In the specification

The specification is amended on page 1 and pages 4 and 5 to correct improper spacing between headings and specification text and drawing descriptions. A line break was inserted between "TECHNICAL FIELD" and "The" on page 1 at paragraph 0001. A line break was inserted between "BACKGROUND ART" and "Acoustic" on page 1 at paragraph 0002. Line breaks were inserted proceeding "Figure 2", "Figures 3a and 3b", "Figures 4a to 4e" and "Figures 5a and 5b" on pages 4 and 5. Replacement pages 1 and 4 to 5 are provided herewith.

SPECIFICATION

Electronic Version 1.2.8

[Acoustic Logging Tool]

Cross Reference to Related Applications

This application is a continuation of US application number 09/674,192, which is a 371 of PCT/IB/98/00646 filed April 28, 1998.

Background of Invention

[0001] TECHNICAL FIELD

The present invention relates to acoustic logging tools, and in particular to aspects of a receiver section for an acoustic logging tool in which the interfering effect of flexural waves is minimised.

[0002] BACKGROUND ART

Acoustic logging tools are used in the evaluation of formations surrounding boreholes such as are used for extraction of hydrocarbons. Figure 1 shows a schematic view of a prior art acoustic logging tool such as the DSI Dipole Sonic Shear Imager of Schlumberger. The tool comprises a sonde 10 which is lowered into a borehole 12 by means of a wireline cable 14. The cable is used both to support the sonde 10 and provide a power, control signal and data transmission path to the surface unit 16. The sonde 10 includes a transmitter section TX capable of generating dipole and monopole acoustic signals, a sonic isolation joint SIJ, a receiver section RX, and an electronics cartridge EC. The receiver section RX includes a number of spaced receiver stations, typically eight stations are used, and each station has typically four piezoelectric sensors for measuring pressure in the borehole due to passing acoustic waves. Examples of various aspects of such a tool can be found in US 4,850,450; US 4,862,991; US 4,872,526; US 5,036,945 and US 5,043,952.

[0003] In dipole logging, the transmitter TX generates a dipole acoustic signal which propagates along a number of possible paths to the receivers RX_1, RX_2 (only two station are shown here instead of the usual eight for purposes of clarity). These paths which are shown schematically in Figure 2, are (1) along the sonde itself, (2) through the fluid filling the borehole, and (3) as a formation/borehole mode in which the signal passes from the transmitter through the fluid in the borehole to the formations surrounding the borehole where a surface wave mode of the

sleeve. This tends to reduce the spring constant/increase flexibility of this portion so increasing the flexural slowness of the sleeve (speed of flexural propagation along the sleeve). In one embodiment, two alternating window widths are chosen, for example alternating 45° and 25° windows. It is preferred to configure the window section so as to inhibit coupling with higher modes of vibration (such as hexapole). This is achieved by selecting the number of windows and the relative dimensions of the windows (for example, alternating sizes as described above).

[0010] The second apertured portion (the slotted section) portions are provided with typically three rows of thin circumferential slots with enlarged portions at the ends ("dumb-bell" shaped slots). The axial length of the slotted section can be reduced while the mass is essentially the same as the corresponding structure in the prior art sleeve with regular slots. The ratio of the width of the centre portion of the slots to the radius of the end portions is typically at least 1:4, 1:6 being preferred. The slots typically define 70° arcs. Each row of slots is displaced relative to the adjacent row(s). This displacement is conveniently 90° although other angles might be appropriate.

[0011] In the receiver section, the pressure sensor (hydrophone) mounts are preferably made massive, constructed from steel. The hydrophones themselves are mounted axially (vertically) so as to be less susceptible to tool vibration caused by coupling of borehole modes. The receiver section has a central mandrel to which spacers are attached, each spacer carrying the weight of the receiver mount above through a compliant pad. Thus each receiver mount is essentially independent of its neighbours.

[0012] A basic concept which is used in constructing a tool embodying the present invention is to ensure that the flexural dispersion (slowness vs. frequency) of the tool does not overlap with the flexural dispersion of the formations of interest at the frequencies of interest. For example, where formations having a slowness of 1200 μs/ft are to be measured, the tool is designed such that tool flexural arrivals do not occur below that speed.

Brief Description of Drawings

[0013] Figure 1 shows a schematic view of a prior art acoustic logging tool;
Figure 2 shows the paths for dipole signals from an acoustic logging tool transmitter to receiver;
Figures 3a and 3b show general and partial cross section views of a prior art sleeve for use in an acoustic logging tool;
Figures 4a to 4e show general and detailed view of a sleeve according to one aspect of the invention;

Figures 5a and 5b show partial general and cross section views of a receiver section according to one aspect of the invention.

Detailed Description

[0014] A sleeve for an acoustic logging tool incorporating the present invention is shown in Figures 4a to 4e. The sleeve is formed from a steel cylinder with a number of openings or apertures cut into it by means of laser machining. The sleeve structure has two main parts, a first portion A having windows cut into the sleeve, and a second portion B defining a slotted section. This sleeve behaves conceptually as a spring-mass-spring-mass... system in flexural mode; the bars in the window sections A acting as the springs and the slotted sections B acting as the masses.

[0015] Each window portion A has eight rectangular windows W separated by bars B. In the embodiment of Figures 4a and 4b, alternating sizes of windows (25° and 45 °) are used with regular (10°) bars (see Figure 4c (section on line AA of Figure 4b)). These dimensions give suitably low spring constant for this section. The dimensions and number of bars/windows can be chosen to optimise this aspect of the sleeve"s behaviour. In this particular case, the windows and bars are about 8cm long. By selecting alternating window sizes and reducing the number of windows to eight, coupling of higher modes of vibration (such as hexapole) into the tool is inhibited. The particular dimensions and number of windows, and the symmetry of the window section can be varied to optimise this behaviour if required.

[0016] The simple slots in prior art sleeves (Figures 3a and 3b) are relatively easy to manufacture but suffer from stress concentration around the end portions. This impacts on the strength of the sleeve and places a limitation on the closeness of the spacing of the slots. Making the slots wider but keeping the same length would decrease the stress concentration but would also decrease the mass of the slotted section (i.e. the "mass" in the "mass-spring-mass..." system) and have a detrimental effect on the flexural behaviour. The sleeve shown in the Figures 4a to 4e uses "dumb-bell" shaped slots, the narrow centre portions Sc give increased mass to the slotted portion B while the enlarged end portions Se of the slots act to relieve stress concentration. The end portions of the sleeve have 8mm radius but